Chart design revision could enhance safety of non-precision approach and landing operations

The design of non-precision approach charts could be improved by providing the pilot with a stabilized, 3-degree approach profile.

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THE PROBLEM posed by shallow final approach slopes in non-precision instrument approaches is being considered by a number of operators. One international operator has identified many non-precision approaches where the procedure appears to produce a shallow approach. State aviation authorities and operators have for many years supported the use of a standard approach slope of 3 degrees for all types of approach — visual and instrument, precision and non-precision. This is a part of the doctrine of the stabilized approach, which is considered vital to the safety of approach and landing operations. A 3-degree approach slope gives a rate of descent of 300 feet per nautical mile, or a 5 per cent descent gradient. Pilots are taught to approach a runway on a 3-degree slope and this, in general, is the approach provided by precision approach and visual approach slope indicator systems. As an extension of this concept, it follows that level flight should not be entered at the minimum descent altitude (MDA): instead, if visual contact is established, the descent is continued to land and, should no visual contact occur, a missed approach is initiated.

When designing a precision approach, the procedure designer considers the approach slope as an integral part of the design. Since glide slope guidance is provided on the profile shown on a precision approach chart, it is expected that the pilot will fly the procedure.

In the case of the non-precision approach, however, there is no consideration of the approach slope other than not exceeding the maximum descent rate of 400 feet per nautical mile. The profile shown on a non-precision approach chart is not then the profile that the pilot should fly but the one that provides the minimum prescribed obstacle clearance. The result is that a profile on a non-precision approach chart may show an apparent approach slope well below the desired 3 degrees. The profile shows, in effect, an obstacle clearance surface.

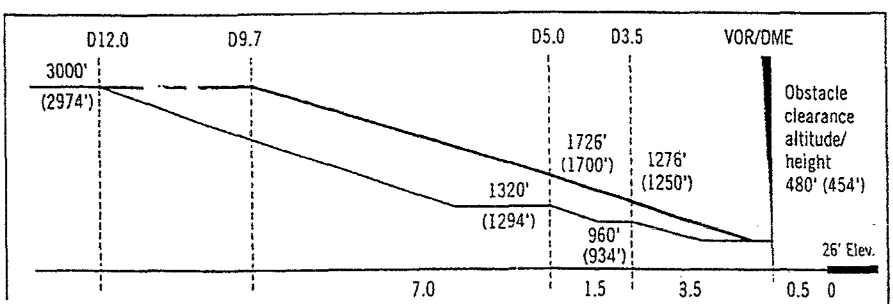
In the same way that pilots are trained and conditioned to fly 3-degree approaches, they are trained to fly the procedures given on an instrument approach chart. When a pilot accurately flies the profile for a non-precision approach, the approach is conducted with the minimum allowed obstacle clearance. It must also be remembered that the altitudes given are for international standard atmosphere (ISA) temperatures and the allowances have to be made, particularly in very cold conditions, to maintain the required clearance.

There are two problems. There is a difference in the type of information provided on a non-precision approach chart from that provided on a precision approach chart. There is also a difference between the outlook of the procedure designer and that of the pilot. The procedure designer provides obstacle clearance information for a non-precision approach. As a result of training and conditioning, however, the pilot will probably treat the non-precision profile as the procedure to be flown.

The ability to approximate a 3-degree approach slope has been available, where distance measuring equipment (DME) is provided, for many years. Many instructors have been teaching that non-precision approaches should be flown with a steady rate of descent of about 300 feet per nautical mile, even when no distance information is available. We now have increasing numbers of aeroplanes which are capable of internally generating an angle of descent. We also have navigation systems that can provide distance information.

It is apparent, therefore, that we should change the philosophy applicable to non-precision approach charts and provide on the profiles of those charts the desired, or 3-degree, approach which the pilot can fly while maintaining the normal stabilized approach procedures. Such an action would also effectively eliminate many of the stepped non-precision approach procedures since the 3-degree profile would be, in many cases, higher than the profiles currently provided on these charts. This logic cannot of course be applied where obstacles demand a steeper than 3-degree approach. Action to introduce a profile to be flown would materially increase the safety of non-precision approach and landing operations. The accompanying figure illustrates these points.

Discussion is required to finalize how best to include optimum flight path guidance on non-precision approach procedure charts while still showing the obstacle clearance information. It is time that this problem was solved. ☐



Non-precision profile showing a 2.2-degree slope (black) having a descent rate of 234 feet per nautical mile and a descent gradient of 3.66 per cent. Desired 3-degree slope is superimposed (green).

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THOUGHTS ON THE SUBJECT OF NON-PRECISION INSTRUMENT APPROACH PROCEDURE DESIGN FROM THE POINT OF VIEW OF THE PILOT. CONCENTRATING UPON:

THE DESCENT GRADIENT PROVIDED IN SUCH APPROACH PROCEDURES;

THE POSSIBILITY THAT MULTIPLE PROCEDURES TO THE SAME RUNWAY, USING THE SAME NAVIGATION AIDS, COULD BE RATIONALIZED; AND

INCLUDING THE WAY IN WHICH THESE PROCEDURES ARE PRESENTED ON COMMERCIALLY AVAILABLE APPROACH PLATES AND IN THE APPROACH INFORMATION PROVIDED IN STATES AIPs.

INTRODUCTION

The problem of shallow final approach descent gradients has been raised of late, particularly by the CFIT Task Force, Aircraft Equipment Group at its recent meeting in Montreal. One major international operator, concerned with this problem, has identified ?? non-precision approaches where the final descent gradient is less than 4.3%, 2.5 degrees, at ?? different aerodromes in ? ICAO Regions. This operator has specified descent schedules for use by its own flight crews which provide a descent gradient of at least 2.5 degrees.

DISCUSSION

Pilot-training staff have been teaching for many years that the only way to conduct a consistently safe approach is to fly a stabilized approach. This means that, even in "visual" conditions, the aeroplane should be set up in the landing configuration with appropriate steady airspeed and power by the time it descends through 500 feet above touchdown. In the case of any instrument approach procedure this means that the approach must be stabilized from the commencement of the final descent. In the case of the non-precision approach, current teaching is that a stabilized approach should not include a change to level flight at the minimum descent altitude (MDA), whilst a visual search for the approach area and runway is made.

Pilots are taught that the correct flight path is a 3 degrees approach, or 5%, which equates to a descent of 300 feet per nautical mile. This is normal practise and most precision approaches approximate to 3 degrees. The standard setting for visual approach slope indicators (VASIS) is 3 degrees. Pilots know the configuration and the power requirements needed to achieve this approach slope (with appropriate adjustments for wind and loading). Pilots also become accustomed to the view of the aerodrome and the runway from a 3 degree approach. A 3 degree approach is the normal visual approach without any aids.

Descent on a non-precision approach should approximate to 3 degrees and, should the runway environment not be in view, when the aeroplane reaches the MDA, a missed approach procedure should be commenced. There should not be a level flight element at the MDA.

The concern here is with approaches at the great majority of aerodromes world-wide and not with special requirements or situations where, for example, a separate access landing system might be developed for the larger jets and commuter traffic.

The development of the 3 degree approach was no mistake, it is suitable for past and current aeroplanes. A steeper approach causes difficulty in airspeed control; there is insufficient drag, power may have to be reduced perhaps below that which provides adequate response to thrust demands. A shallower approach requires increased thrust which results in increased fuel consumption and noise; the view of the approach area deteriorates; most importantly, the aeroplane is closer to the terrain, at all stages of the descent, than is necessary. In either case the view of the runway from the final approach is not that to which most pilots are accustomed. Pilots are accustomed to the view from the 3 degree approach slope. This is not to say that some aeroplanes are not compatible with approach slopes greater than 3 degrees.

Any factor which deviates from normal practise is a potential hazard. The investigation into the problem of controlled flight into terrain (CFIT) accidents has revealed that there may be such a hazard in non-precision instrument approaches where they deviate from the optimum. There are approaches where the descent gradient is well below 5%, 3 degrees; one has been identified where the approach is less than one degree. A one degree approach gives a descent rate of 100 ft/nm. There are also non-precision approaches where the angle of the approach is well above 3 degrees.

Another problem is posed by stepped descents in non-precision approaches. The use of a stepped procedure is contrary to the need to generate a steady descent to the MDA. Also the manner in which the vertical profiles of stepped approaches are shown on approach plates invites early descent to the step altitude. This type of depiction is not shown in the Aeronautical Chart Manual. Stepped approaches have been identified where the use of an optimum descent would eliminate any need for the steps. In these cases the entire approach, down to MDA would, if a 3 degree approach were used, be above the vertical profile of the current, stepped, procedures. It is probable that this would apply in many more cases and many stepped procedures could therefore be eliminated.

It is possible to understand that there may be cogent reasons for a descent gradient that is steeper than the optimum. ICAO PANS OPS (Doc 8168) states that the descent gradient, or slope, for the final descent in non-precision operations, should not exceed 5%, 3.0 degrees (PANS OPS, Vol II, Part III, 26.4.5). This paragraph further states that where a steeper descent gradient is necessary, the maximum permissible is 6.5%, 3.7 degrees. PANS OPS, whilst quoting an optimum final approach descent gradient, and a maximum, does not give a minimum descent gradient. The gradient is calculated from the distance from the final approach fix to the threshold, and the vertical distance between the height over the final approach fix and 15 m (50 ft) over the threshold.

Pilots may find it difficult to understand why it should ever be necessary to design an instrument approach procedure with a slope of less than the optimum. From an examination of the rules of procedure design, which starts with the departure from the approach fix into the procedure, from the altitude of the highest minimum sector altitude (MSA), it appears that approaches may be made to fit into the airspace below this MSA. Many instrument approaches do commence from an altitude above that of the MSA, however, it does appear that procedures are designed paying attention to the wrong priorities. It appears that instrument approach procedures are designed from the top down, whereas logically these procedures should be designed from the ground up, based on a 3 degree approach, unless there were unavoidable reasons for a steeper approach. PANS OPS, Volume II, Part III, 1.4, refers to segment application and that the final approach track should be identified first. This paragraph does not state that the final approach profile should also be a controlling factor.

The current concept of efficient use of airspace may concentrate on the use of airspace in the terminal area. It is time that this concept was reversed and the priority given to the safety of the approach to land operation. This may mean that a particular instrument approach procedure may have to be redesigned to commence at a higher altitude. The overriding requirement must be for the safe approach and landing of the aeroplane. The provision of a safe approach would surely be the most efficient use of airspace.

The Instrument Flight Procedures Construction Manual (Doc 9368) contains more than one example of non-precision approaches which show the final approach descent gradient to be less than 3 degrees. The manual also shows approaches where a change in the descent gradient is indicated, from a figure less than the optimum to the optimum of 3 degrees. As stated above, it is difficult to understand why a descent rate of less than the optimum should ever be necessary. Such problems are illustrated on pages 3-19/3-20, 4-5/4-6, 5-7/5-8, and 10-6/10-7 of Doc 9368. Any of these examples may, in the absence of any definition of a minimum approach gradient, lead an instrument approach procedure designer to design an approach with a below optimum descent gradient. In some of the cases a higher, and optimum, descent gradient would resolve the problem that the designer was trying to solve with a stepped descent or a varied rate descent.

Other problems related to procedure design concern how these procedures are presented on approach plates. The problems examined here are those in the presentation of alternative approaches. The procedure provided for a VOR approach when the DME element of a VOR/DME approach is not available or the procedure provided for a localizer only approach when an ILS glide slope is not available. Annex 4, 11.10.6.2 c), states that the missed approach procedure profile should be shown by an arrowed broken line. Annex 4, 11.10.6.2 d) states that the profile for any additional procedure should be shown by an arrowed dotted line. This usage also applies to tracks. Guidance material in the Aeronautical Chart Manual (Doc 8697), pages 7-11-15, 7-11-17 and Specimen Chart 9, and in Circular 187, Instrument Approach Chart - ICAO, Guidance to Chart Makers provide illustrations of the Annex 14 Standard. Improper, use is made of the broken line in both commercial and State material to indicate the vertical profile for additional approaches.

Profiles for non-precision approaches are also shown in a manner which invites pilots to carry out an early descent to the MDA and then to maintain level flight at the MDA, to the missed approach point. It should also be noted that Annex 4, 11.10.6.2 b), c), d) and e), Doc 8697 and Circular 187 all use the word "track" where "profile" should be used. The heading to Annex 4, 11.10.6 should also be amended to read "Portrayal of procedure tracks and profiles".

Some examples are given below to illustrate the types of problems with the slope of the final descent, stepped descents, and the presentation of the approach procedures, which have been described above. They occur both on commercially available approach plates and on approach procedures contained in States AIPs.

Non-precision approach - shallow final approach descent gradient.

The first example (Fig.1) shows a VOR/DME or a VOR approach where the MDA/H for both approaches is 1960/395 ft.

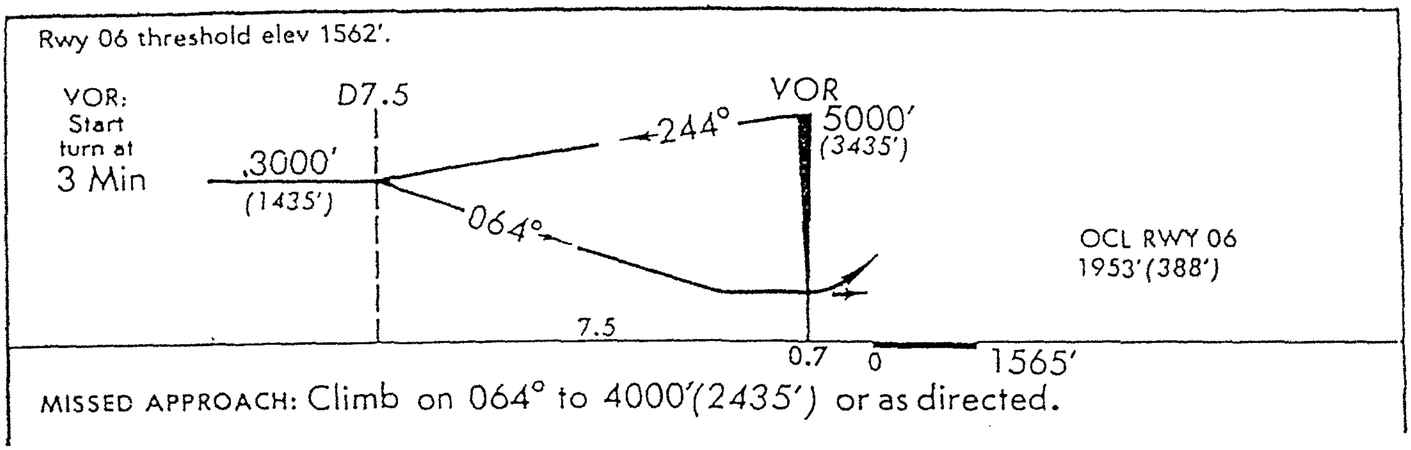

Figure 1. VOR/DME and VOR
(source - commercial approach plate,
the State AIP gives the same information)

The distance provided for the final descent is 8.2 nm. The height through which the aeroplane must descend from the procedure turn to reach a point 50 feet above the threshold is 1385 feet. This gives a required descent rate of 170 ft/nm, an angle of 1.6 degrees. Considering the same distance for the final approach, a 3 degree approach would require that the procedure turn was raised by 1075 feet. To maintain the same final distance the procedure turn should be at an altitude of 4 000 feet (to be exact 4 075 feet).

Two accidents involving hull losses have occurred on this particular non-precision approach. Both aeroplanes, a DC-8 and a B 707, struck the terrain, within 1 nm of each other, at approximately 9 nm on finals, at night. In each case the crash occurred at a greater distance than that at which the final descent should have been commenced. It is not possible to say what difference a 3 degree approach slope for the procedure would have made, other than to say that such a change might have broken the accident chain in one, or both cases. Since we have not received ADREP reports for either of these accidents we do not know whether the navigation aids were even working.

Non-precision approach - shallow stepped approach.

The second example (Fig.2, 3 and 4) shows three shallow stepped VOR/DME approaches, to the same runway, where the MDA/H is 480/454 ft in each case.

The same commercial source provides these three procedures, VOR DME-1, VOR DME-2 and VOR DME-ARC, to the same runway using the same VOR/DME facilities. By comparing the vertical profiles in Figures 2, 3 and 4 it can be seen that all are shown as stepped descents, the average descent gradients are all well below 5%, 3 degrees. The final descents, for the three approaches, commence from two different altitudes and three different DME distances; the check DME points are either different, or if the same, indicate a different check altitude. The only features in which the three procedures agree are in the use of the same VOR/DME facility and the same MDA/H.

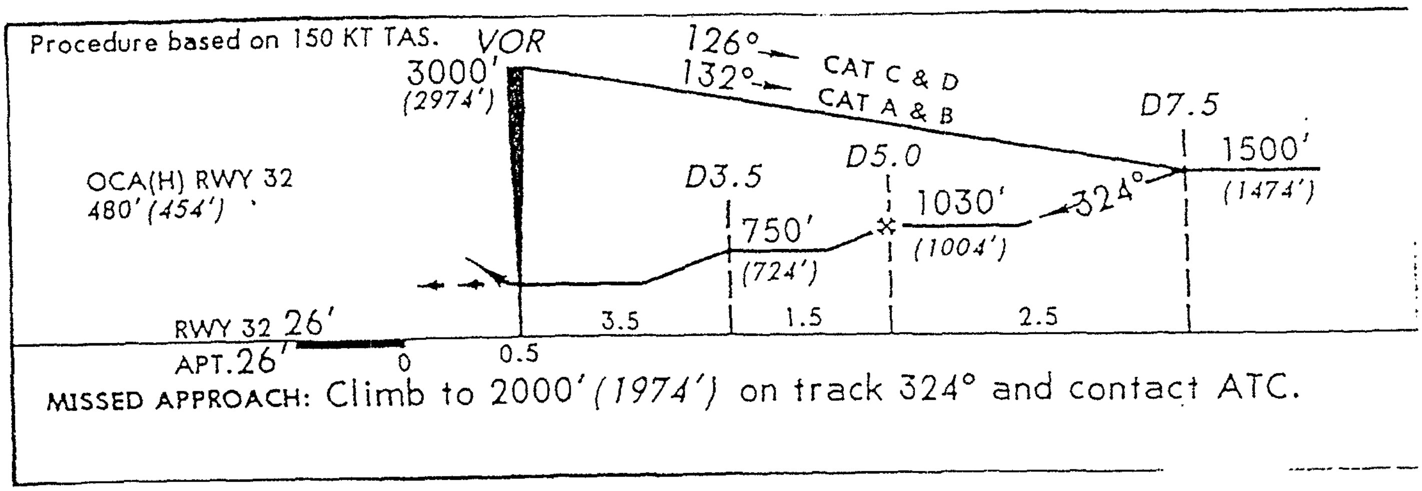

Figure 2. VOR DME-1
(source - commercial approach plate)

The procedure departs the VOR at 3000 ft QNH, commences a level turn at 7.5 DME at 1500 ft QNH. Distance to threshold 8 nm, descent 1424 ft, average 178 ft/nm or 1.67 degrees.

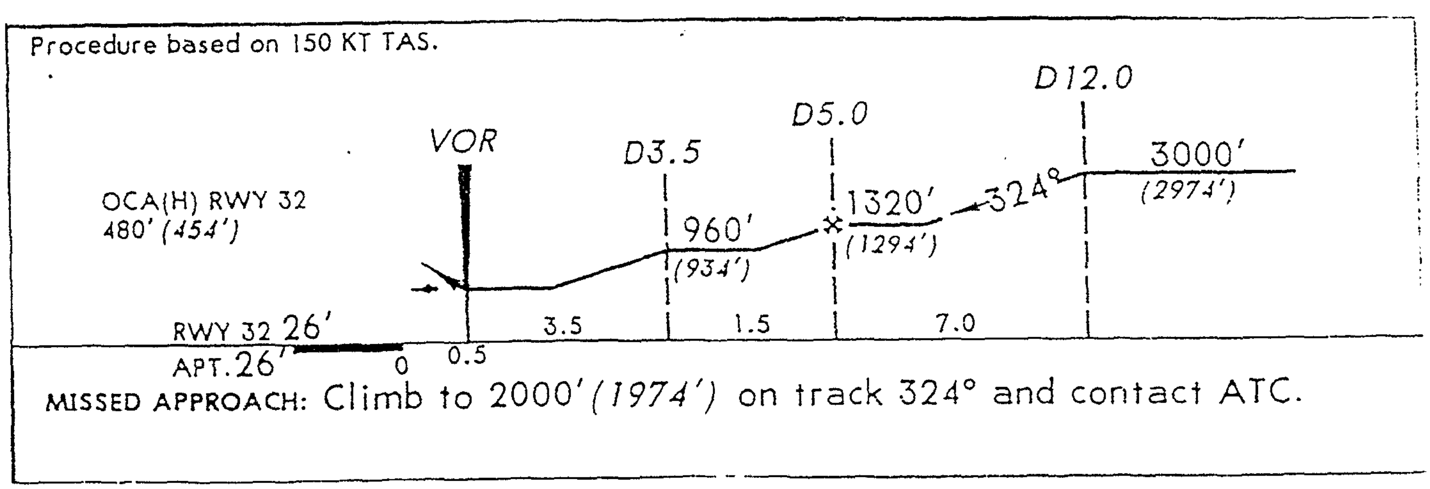

Figure 3. VOR DME-2
(source - commercial approach plate)

The procedure departs a holding fix at 12 DME on the extended approach at 3000 ft QNH commencing immediate descent. Distance to threshold 12.5 nm, descent 2924 ft, average 234 ft/nm, 2.2 degrees.

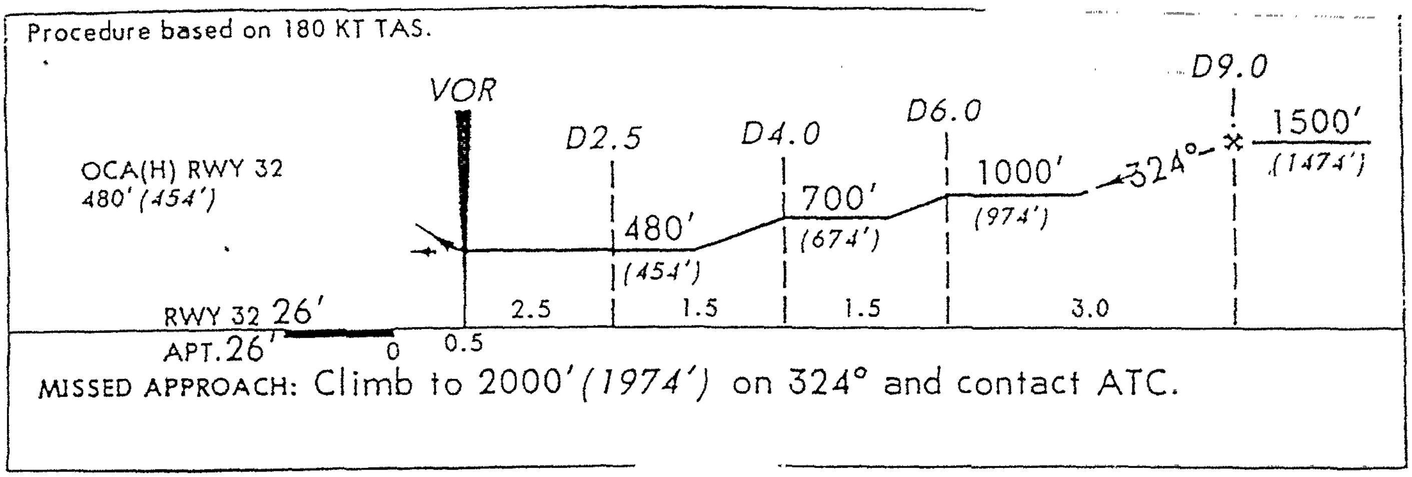

Figure 4. VOR DME-ARC
(source - commercial approach plate)

This procedure is based on a 10 DME arc flown at 3000 ft QNH. The final descent commences from 9 DME at 1500 ft QNH, distance to threshold 9.5 nm, descent 1424 ft, average 150 ft/nm, 1.4 degrees.

Information available from the State AIP, held in ICAO, covers only the VOR DME-ARC procedure. The vertical profile from the AIP is shown in Figure 5.

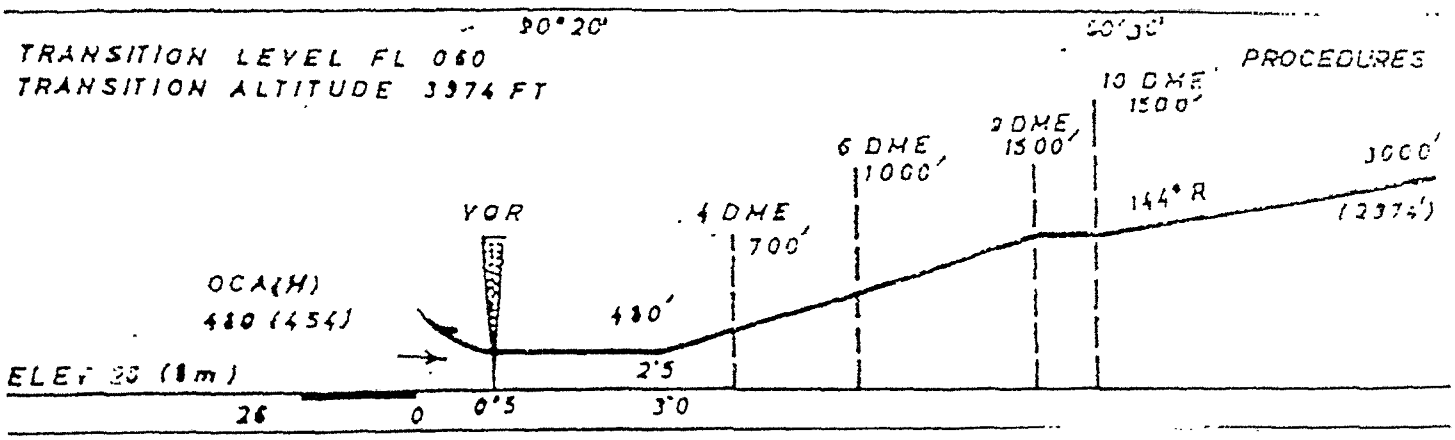

Figure 5. VOR DME-ARC
(source - State AIP)

Whilst Figure 5 does not show a stepped approach, the descent to the threshold is again 150 ft/nm, or 1.4 degrees. Figures 4 and 5 show arrival at the MDA, 480 ft, at a distance of 3 nm or more prior to the threshold. At 3 nm on this approach the altitude, for an optimum descent, should be 1000 ft (in fact 3 x 300 + 50 + 26 = 976 ft).

Approach plates for the VOR DME-1, VOR DME-2 and VOR DME-ARC approaches to the this same runway are provided, for direct comparison, in Figure 6. There would not appear to be any reason why the three stepped final approaches to this runway should not be eliminated, and a 3 degree approach slope instituted. The descents should commence at the same DME and altitude. This would provide standardization for the approaches to the same runway, and the optimum approach slope. The check DME distances and altitudes on the descent for the final approach should be the same for each of these similar approach procedures. Different procedures will be required to bring aeroplanes to the inbound final track and to the point at which the descent should be commenced.

Non-precision approach - misleading depiction of vertical profile.

The third example (Fig.7 and 8) shows an alternative localizer approach for an ILS glide slope out situation. The vertical profiles are taken from a commercial approach plate and from the AIP. The vertical profile shown in Figure 7 is a direct invitation to the pilot to make an early descent to the MDA. The ILS DA/H is 1814/252 ft and the LOC (GP out) MDA/H 1920/358 ft.

Figure 7. ILS and LOC (GS out) approach.
(source - commercial approach plate)

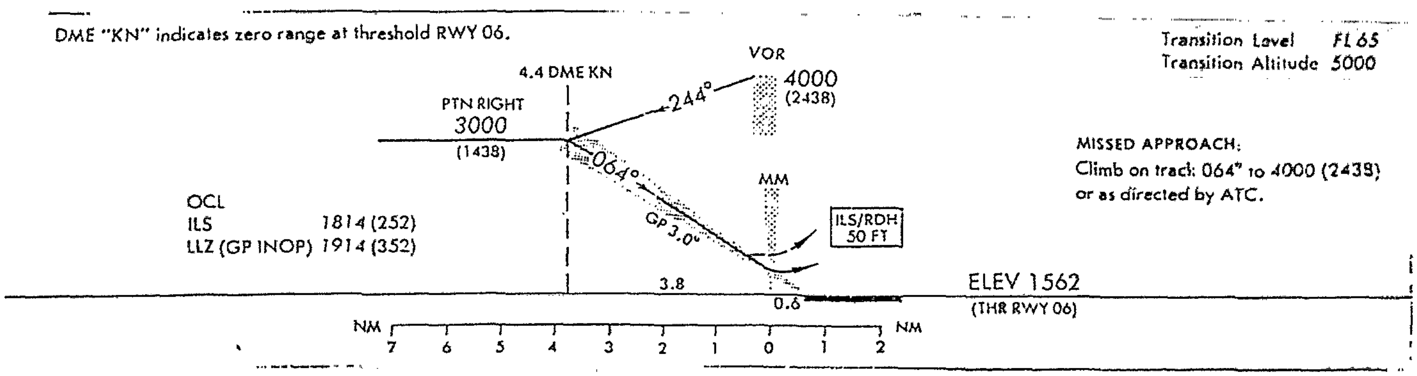

Figure 8. ILS and LLZ (GP INOP) approach.
(source - State AIP)

Figures 7 and 8 show information for the same approaches, with a misleading depiction, an invitation to early descent, with improper use of the broken line, to show the alternative approach, in Figure 7.

INFORMATION ON NON-PRECISION INSTRUMENT APPROACHES WHERE THE FINAL APPROACH IS LESS THAN 2.5 DEGREES. PROVIDED BY A MAJOR INTERNATIONAL OPERATOR

(material yet to be received from British Airways/AERAD)

CONCLUSIONS

1. It must be accepted by all operational personnel that standardization of instrument approaches and the use of the optimum final approach descent gradient is a major flight safety objective which would increase the safety of the approach to landing phase of flight. This is where the majority of accidents occur.

2. Non-precision instrument approaches should be designed with the priority on the optimum, 5%, or 3 degree, final approach descent gradient.

3. ICAO should publish a minimum final approach descent gradient in PANS OPS and apply more emphasis on the use of the optimum of 3 degrees .

4. ICAO instrument approach procedure design guidance material should be revised to ensure that there is no encouragement to design shallow approaches.

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5. Immediate efforts should be made to have all non-precision approaches, where the final approach is less than 2.5 degrees, redesigned to a minimum of 2.5 degrees and preferably to 3 degrees.

6. Non-precision approaches that are stepped, and average less than a 3 degrees, should be redesigned with a minimum 3 degree approach which would eliminate many stepped procedures.

7. Efforts should be made to ensure that the depiction of a vertical profile for an alternative non-precision approach does not invite pilots to conduct an early descent to the MDA.

8. Efforts should be made to ensure the usage of arrowed broken and dotted lines, as set out in Annex 4, 11.10.6.1 and 2. Broken lines should not be used to show the vertical profiles, or tracks, of additional approaches, only for showing the missed approach profile and track.

9. Annex 4, 11.10.6 and the Aeronautical Chart Manual (Doc 8697) should be amended to properly reflect the different usage between "track" and "profile".

10. The Aeronautical Chart Manual (Doc 8697) should be expanded to include illustrations of various types of instrument approach procedure.

RTS 8 April 1994